COÖPERATIVE RESEARCH IN PROBLEMS OF WATER PURIFICATION[1]

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To the practical water works man, "research" frequently connotes investigative effort directed into abstract fields to develop scientific axioms. The publication of such material is haled with delight by bespectacled and ethereal scientists and with suspicion and perplexity by those upon whom rests the duty of converting unpalatable mud into the clear and sparkling elixir of life. To present a paper, therefore, upon a subject which combines in it the scientific and the practical, it is necessary to demonstrate that research of highly specialized and scientific character is necessary in problems of water purification and that coöperative rather than individualistic investigative effort should be the desideratum. The first of these hypotheses should concern more particularly the man in the works upon whom rests the responsibility of adopting the scientific methods and of absorbing the new truths which the investigator discloses. To the experimenter the second problem is of interest. In it the distinction between isolated and concerted attack upon the unsolved problems of science is made clear. It is the present purpose to outline in brief these two phases of coöperative research in problems of water purification. For purposes of clarity, however, the second phase will be discussed before the first.

COÖPERATIVE VERSUS INDIVIDUALISTIC RESEARCH

Scientific investigation in the field of water purification has progressed for a number of decades, but it may be stated with safety that during this entire period the study of problems has been, for the most part, intermittent, sporadic and disconnected. The development of data has been the result of local efforts in the laboratories

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of individual colleges, states, municipalities, or private corporations. What coöperation has existed has been localized and not national. Dr. Burton E. Livingston of the Johns Hopkins University describes this situation in excellent terms when he states: "there appear to be a large number of good experimenters who do not have well-selected problems in mind, who work on that which lies close to them rather than on that which seems to be most fundamental, most far-reaching or most imperatively needed for the growing structure of knowledge."[3]

The history of individualistic research effort in water purification, as in a number of allied fields, has been that of "a kind of guerilla warfare upon the unknown."[3] While such warfare may result in temporary victories over isolated problems, in intermittent eliminations of difficulties in one place, it never produces a complete surrender of natural opposing forces to the control of man. The solution of the problem of chlorinating the St. Lawrence River water, for instance, while of immediate value, is of but little aid in solving the general problem of chlorination of waters, unless the methods, conclusions and conditions of the first problem are subjected to the composite scrutiny and checking of coöperative workers elsewhere. It is true, no doubt, that under present conditions the individual scientists find it difficult practically to choose arbitrarily that line of study which seems to promise more remote but more valuable results, while the material at hand has the attractiveness of immediate practical application, if only to the restricted field with which he is familiar. Every problem will be solved, however, more satisfactorily and more permanently if the attack is made from many viewpoints, under different conditions, and by various investigators. The personal stressing of unimportant aspects, the individual errors, the apparent but unreal significance of local characteristics, and the restricted mental conception of a problem, are all likely to be eliminated or reduced by coöperative research, with the ultimate production of a sounder and a more accurate series of scientific observations and conclusions.

It seems hardly necessary to emphasize the abstract desirability of solving the problems of water purification by a more constructive system of coöperative effort than now exists. It is of value, however, to direct the attention of the members to the fact that this

[3] Livingston, Burton E., Constructive Scientific Research by Coöperation, *Science*, March 19, 1920.

organization may serve as an excellent medium through which to inaugurate a comprehensive system of coöperation. In this manner, we may do much to advance scientific knowledge and its practical application. It has been pointed out that coöperation in research involves "the union of a number of minds in planning the attack on a problem, in working out the different parts, and in bringing the several component results together into a well-considered presentation that might really mark a tangible advance in scientific knowledge."[3] These various functions the American Water Works Association can and should perform. It should not be a difficult matter to supply that "union of minds" to plan the attack on a series of problems by the proper organization of a research committee. To subcommittees in turn may be delegated the further task of "working out the different parts and bringing together the several component results." It is these functions of coördination and initiation in coöperative research which the author wishes to suggest to this body. As far as he is aware, no other organization is at present so well suited to undertake its development and no other has yet deemed it desirable to assume this responsibility. The intention is to indicate the desirability of this Society fostering actively the principle of coöperative research. The specific mode of action of such a research committee and the possibilities of its coöperation with other organizations, such as the National Research Council, are simply matters of detail.

Granting the abstract desirability of developing such coöperation, what are some of the problems which today remain to be solved? Although considerable advance in the practical methods of water purification has taken place in the United States, may we state definitely that the fundamental laws of coagulation, filtration and chlorination are accurately known? If so, are these laws applied in every-day operation? Some of us, perhaps, are not so sanguine about our complete understanding of the processes involved in the above mechanisms of purification. An opportunity to engage in a coöperative attack upon such problems will be welcomed. In order to make clear some of these unsolved difficulties, the second portion of this paper is devoted to a brief survey of a few of the possible fruitful sources of investigative work. These possibilities doubtless are already known to most of the members, but summarizing them in this connection may make more apparent the necessity for the plan which this discussion has set forth.

SOME UNSOLVED PROBLEMS IN WATER PURIFICATION

a. Coagulation and sedimentation. The factors determining effective coagulation and sedimentation of waters differ in degree with different waters, but their characteristics in general are the same, regardless of the nature of the water. The effects of time, temperature, agitation, and hydrogen-ion concentration upon coagulation have been studied only superficially. The material for such study has been accumulated in a number of different fields in allied sciences, but has not yet been adapted to water purification problems. It is stated often, for example, that the formation of satisfactory floc is retarded by low temperature and by inadequate agitation, yet how many plants observe and record the nature of the floc produced each day, so as to provide the material for correlated study of its variations with other characteristics of the water during an entire year? Isolated observations of inadequate floc formation which are roughly and often fallaciously connected with temperatures aid little in pointing out fundamental principles. An adequate measure or series of measures of the characteristics of floc offers an excellent research problem, the solution of which would aid considerably in the studies of water works control.

The measurement of floc formation in its various aspects, however, should be preceded by a study of the raw waters with a view to determining a more accurate and satisfactory method of apportioning coagulant to raw water to obtain satisfactory coagulation. The usual method of turbidity reading, with adjustments for rising, falling, constant, fine, medium, and coarse turbidities, leaves much to be desired, particularly when frequently the actual procedure results in abandoning all methods other than adding chemical until the coagulation becomes satisfactory. These methods are necessarily wasteful, since for each water there exists a critical concentration of coagulation which is most effective and economical. Can we not devise a satisfactory index to the "coagulant demand" of a water by a simple test? When it is borne in mind that the flocculation of waters is dependent upon the nature and amount of fine particles present, it would appear that the search for such a measure should be in the field of colloid chemistry. It is suggested that perhaps the use of a nephelometer, an instrument measuring the cloudiness of a water, may be developed to study the character of a water after a very brief period of settling when the coarse material

of low "coagulant demand" has been removed. It would be interesting to learn what such "post-settling" turbidity readings would disclose as to proper chemical dosage. An experimental quantitative study of the "coagulant demand" of the various sizes of particles in the same water should prove interesting and valuable.

Another phase of the coagulation problem which has taken on an importance in recent years is the effect of the varying hydrogen-ion concentration upon flocculation. There appears to be an optimum range of P_H within which the coagulation proceeds most satisfactorily. Water works operators and investigators should begin to accumulate complete data regarding the P_H values of different waters in the country under all conditions. In Maryland the State Department of Health has been making, for several months, determinations of hydrogen-ion concentration on all waters and has instituted these tests as a daily procedure in several large filtration plants. It is too early to predict the results of these studies, but, at any rate, material should be collected to determine the importance of this characteristic.

The study of sedimentation problems in the light of recent developments in physical chemistry may require some modifications in our older concepts. The effect of electrolytes, of competing and protective colloids, of surface tension and osmotic pressure are of more than purely scientific interest. Recent work has demonstrated, for instance, that the Brownian movement is observed with practically every type of clay suspended in water, varying from the rapid motion of the finest particles to the more sluggish one of the larger particles or aggregates or when hampered by the presence of electrolytes.[4] An extended journey into the field of physical chemistry promises an excellent return to the water supply investigator.

b. Filtration. The internal forces within a sand filter bed are of greater magnitude than is generally realized. Experience in Maryland with a number of peculiar phenomena in filter beds has disclosed a startling variety of forces released in filter beds, which appear to be intimately connected with the character of sand and of applied water. The appearance of internal contraction in a sand bed of such strength that the surface area of the bed may be reduced by more than 5 per cent of its original area is of importance in calling attention to the unsolved problems concealed within the bed.

[4] Alexander, Jerome, quoted in "Ceramic Processes Associated with Colloid Phenomena," by A. V. Bleininger, *Journal of Industrial and Engineering Chemistry*, Vol. 12, No. 5, May, 1920.

If we consider the whole principle of filtration as founded upon "a sort of instability, both chemical and biological (and physical —A. W.), in the behavior of matter in solution or in suspension, when spread out in thin films over surfaces, or flowing in fine filaments through interstitial capillaries of constantly varying cross-section,"[5] we obtain some idea of the intricacy of the problems. That these problems are of more than academic interest has been clearly demonstrated in the difficulties encountered in the shrinkage of sand beds, in their selective action upon bacteria, in the adsorption of materials in water softening plants, in the sudden discharge of slugs of chlorine taste where chlorine is applied before filtration, and in many other phenomena. The researches of Dunbar[5] and Baldwin-Wiseman[5] on the variations of surface tension within a sand bed and their conclusion that the elimination of a dissolved salt by filtration is inversely proportional to the degree of concentration of the solution mark only the beginnings of the studies on internal forces. The work of the Maryland State Department of Health on the varying adsorptive capacities of different sands and Hannan's observations[6] on the effect of surface electrical charges of sands and of bacteria indicate the promising possibilities of more research in filtration.

c. Chlorination. Sanitarians have established definitely that water may be made safe for potable purposes by chlorination. The water works official, however, must go a step further. He must make the water potable in addition to safe. If the water is unpalatable and objectionable because of tastes and odors, then the problem of chlorination may not be considered as solved. It is only a few years since the conception of the mechanism of chlorine treatment has undergone some modification from the simple hypothesis of direct oxidation. But in this comparatively short period, a series of questions has arisen which is still imperfectly answered.

In this field again we must have recourse to highly technical investigations to aid us in clarifying our concepts of chlorination processes and in controlling their operation. Even today it is difficult to answer definitely whether the action of chlorine is physical, physico-chemical, or chemical, whether its action is selective for different types of bacteria and, if so, what the causes for such

[5] Baldwin-Wiseman, W. R., Statistical and Experimental Data on Filtration, *Proc. Inst. C. E.*, Vol. CLXXXI, 1909–10.

[6] Personal communication.

selection are. The action of other disinfectants is elective and their toxicity is dependent upon their position in definite ionic series and upon the characteristics of the different bacteria, such as their response to Gram stain. The surface character of different classes of bacteria shows a marked influence upon their behavior under different conditions.

Where we attempt to treat raw waters of complex organic and inorganic content, our present methods of control are entirely empirical and not infrequently unsuccessful. The causes of tastes with low doses and the absence of tastes, at times, with excessive doses of chlorine are still in the category of the unknown. It is not a solution of the difficulty to state that tastes and odors may be prevented by proper regulation of applied chemical, for the terms "proper regulation" are indeed broad in interpretation. Proper chlorination control, on the contrary, would seem to be possible of attainment only after a complete understanding of the details of the complex disinfection processes has been reached. May we not call upon this Association to take the lead in the initiation of these studies?